A COMPREHENSIVE APPROACH TO FIRE DETECTION: THE SIGNIFICANCE OF HUMAN INVOLVEMENT OVER AUTOMATION

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ABSTRACT

The present study talks about the relevance of human intervention toward the enhancement of fire detection systems and shows that they compare with traditional automated methods based solely on preset threshold values to activate alarm signals. Traditional automatic detection systems do not have early manifestations of fire because it restricts its activation when readings are crossed over certain limits. In the proposed hybrid model, resident intervention integrates the system to take action on sensor data in real-time. Once a fire is detected, sensor data are sent to a BLE device. From their own observations, residents can confirm and forward alerts to the situation.

This system does not only allow for real-time response but also empowers the community to be involved in fire prevention. Our incentive is in reducing response time and enhancing the accuracy of alerts, especially for small fires that automated systems may fail to identify to point out. It is through conclusions from this study that human oversight in the detection of fire can be seen as a significant thing, given the example of making use of technology in the involvement of the community, then finding a better input for fire response strategies. Further to that, the impact of this hybrid model on varied environments from residential neighborhoods to industrial setting is presented to show that it has the ability to transform the practice of fire safety en totto. As part of a detailed assessment of the pros and cons of integrating human intervention, the present research contributes to the continuing discussion towards improving the detection of fires and other response systems.

KEYWORDS

Human Intervention, Fire Detection, Automated Systems, Community Engagement, Response Efficacy

1. INTRODUCTION

Fire detection systems have progressed from simple alarms to the most complex multi-sensor platforms. In this study, we are going to focus on a system equipped with four key sensors: Flame sensor, Heat, Gas/Smoke, and Photoresistor. Each of these sensors has been tasked to play a crucial role in the identification of possible fire hazards. The Flame sensor detects the type of radiation emissions of flames to enable the system to recognize early. The Heat sensor measures the changes in heat level in the surroundings, essential for observing a rise in temperatures that may be a sign of fire. The Gas/Smoke sensor detects carbon monoxide, one of the products of combustion, and provides very early indications of fire even when the flames are not visible. The Photoresistor senses light intensity whereby a sudden blockage of light, including smoke, can be noticed.

1.1 Role of BLE in Data Transmission

All these sensors together offer a much more accurate and early warning mechanism. When the data sensed by any of these sensors signifies fire conditions, it is transmitted by a BLE device to other systems. These include cell phones. Such a BLE-based communication system allows the residents or the spotters to hand-assess the situation concerning fire before sending a message, thereby adding human intervention in the detection process. Unlike LoRaWAN that is purely automated, this hybrid system is such that it gives real-time choices to the user and works to minimize delays whereas LoRaWAN tends to use a threshold to try to go about generating a signal for making an alarm.

1.2 Distinction from LoRaWAN Automation

Another key distinction of the BLE device from all traditional LoRaWAN devices is in the conception of human engagement in decision-making. LoRaWAN devices are usually fully autonomous. They send warnings once preset thresholds are exceeded. However, such thresholds often prolong response times since systems often wait for considerable levels of detected threats to be exceeded for alarms to be triggered. In our proposed model, on the contrary, verification is within the capacity of the BLE-enabled system with human oversight so that a resident or emergency personnel can do verification in real time. After the resident notice signs of fire, he/she opens an application and scans the BLE device, after which he/she manually triggers an alarm along with sensor data. This step removes dependency on thresholds and has a quicker response time in detecting small signs of fire; thus, the possibility of false positives and tardy responses are reduced to a minimum.

1.3 Leveraging Human (Spotter) Intervention for Effective Fire Response

Human intervention within this system does not supersede the automated detection but acts as a development, owing to the immediate decision-making capability. As has been proven by research, though effective, automated systems can perhaps fail to handle unwelcome changes within the environment and read inaccurately (Zhou et al., 2020). This system does not suffer from the problems described above and remains flexible in dynamic fire conditions allowing humans to visually confirm or reject sensor alerts. This interaction brings in another layer of security; it empowers a community to be involved in preventing fires, rather than just the mechanical systems. More broadly, adding human interference to fire detection systems has implications for safety enhancement of residential neighborhoods, industrial settings, and public spaces, respectively. We thus conceive of a community-engaged fire detection system responsive in which safety comes first. This study contributes to existing bodies of knowledge on fire detection technology while trying to redefine the role of human intervention to enhance public safety protocols. Findings from this research thus carry great implications for future fire safety policies and technologies, providing a collaborative approach to preventing fires.

Being able to integrate both sensor-driven data and human decision-making approaches, the system is assured of the shortest time possible for an accurate response, which is unique to systems adopting this approach only. The whole system empowers the human operator to intervene as soon as possible; therefore, safety factors are brought closer to total effectiveness in the avoidance of catastrophic outcomes. Essentially, the BLE device closes the gap between the automated sensing and human action, that is, a fire detection solution becomes very flexible and effective.

2. METHODS

This research adopts a holistic approach to discuss the workflow of fire detection by multiple sensors and subsequent human intervention for alerting. The methods involved in the research can be broadly categorized into three major stages: deploying sensors, collecting and processing data, and human interaction and response. These are very integral parts of a working fire detection system.

2.1. Sensor Deployment

It is installed with four sensors affixed at strategic points on the power poles in the local residential area. They comprise flame, gas/smoke, heat, and Photoresistor sensors altogether, through which early fire triggers are sensed.

Analog Flame Sensor: Detects heat radiation from flames. It's configured to sense infrared wavelengths typically emitted during combustion.

Analog Gas/Smoke Sensor: Sensitive to flammable gases (e.g., methane, propane), providing early detection before visible signs of fire.

Analog Heat Sensor: Measures abrupt temperature rises, signaling potential fire hazards.

Photoresistor: Measures light intensity and adjusts detection thresholds based on whether it is day or night. This adjustment ensures that the system is sensitive to the environmental lighting, enhancing detection accuracy regardless of external lighting conditions.

Figure 1. Flowchart of the data from the sensors to the spotter

Data Flow

When these sensors detect anomalies, the data is compiled and sent to a **Bluetooth Low Energy (BLE) device**. This BLE device acts as a broadcaster, continuously transmitting sensor readings. A resident or a spotter, noticing potential fire risks, can then scan the BLE device using a mobile app. The app retrieves the sensor data, displaying crucial information about the fire's likelihood based on sensor outputs. The spotter or resident visually confirms the fire and immediately sends an alert through the app, including the sensor data, to notify emergency services.

2.2. Data Collection and Processing

Once the sensors are mounted, they continually take readings regarding environmental parameters. These readings are then transmitted to a central processing unit or microcontroller that aggregates and processes them in real-time. The system uses a threshold value defined at which the alarm condition begins, but what this research has thrown into focus is the human intervention aspect that occurs once potential fire conditions are identified.

The system uses a predetermined algorithm to process information on anomalies such as extreme rise in temperature or gas detection to be able to evaluate the reading against historical data and predetermined thresholds in determining the possibility of fire. Our system does not wait for such specific thresholds to be reached like automated systems before alerting; hence, it involves human intervention as soon as anomalous conditions are observed.

This system feature will be paired with the functionality of sending the system to notify the surrounding residents through a Bluetooth Low Energy connection. The notification is enhanced by provoking the persons who actually create the need for further investigation on the issues. The design of this system encourages the active role of the community for fire safety issues. Algorithms are flexible about real-time modifications using newer data update, giving way to adapting the strategies of response in relation to new information from the situations.

2.3. Human Interaction and Response

Human intervention is the final stage of methodology. The resident or community member is then required to acknowledge the situation through the mobile application by which he is programmed to interact easily with the BLE device. The app will, therefore, offer an interface that is user-friendly in showing sensor data that indicates readings in temperatures, gas concentrations, and

Flame radiation measurements. Users can visually assess the environment and, hence, conclude that if any further action is needed.

When fire is confirmed or even suspected, the user can start an alert from within the application to local emergency services, providing it with detailed information from sensors that could aid in first responders' ability to determine what situation they are stepping into. The process thus bases itself on the fundamental difference between automated systems and the one proposed here: the former based its detection on thresholds, whereas the latter relies on human observation and verification to bypass such limitations in detection. We hope that by incorporating human intuition in the fire detection process, we will be able to deal more promptly and effectively with fire cases and generally improve residential fire safety.

In general, this design places much emphasis on the interaction of advanced sensor technology and human input. Being a multidisciplinary approach, which takes into account proper placement of sensors, real-time processing of data, and active involvement of the community, this research aims to develop an enhanced and fire-sensitive detection system. Results obtained through this study will be significant in enhancing the advancement of fire safety procedures because it helps illustrate and explain why there is a crucial need for human judgement in computerized detection systems.

Table 1. Comparison of Automated Systems and Systems with Human Intervention

Aspect	**Automated Fire Detection Systems**	**Proposed Human-In-The-Loop System**
Detection Mechanism	Relies on predefined thresholds and algorithms.	Utilizes sensor data combined with human observation.
Alert System	Automatically triggers alerts based on sensor readings.	Allows for human verification before alerting.
Response Time	May have delays due to threshold settings.	Immediate action taken based on human assessment.
False Alarms	High potential for false alarms due to threshold sensitivity.	Reduced false alarms as humans can contextualize data.
Community Engagement	Limited; mostly automated with minimal human involvement.	High; encourages community participation and awareness.
Adaptability	Rigid; operates within set parameters and thresholds.	Flexible; can adapt to nuanced situations through human judgment.
User Empowerment	Passive; users rely solely on technology for alerts.	Active; users can take initiative to confirm and report fires.

3. LITERATURE REVIEW

This literature review reviews earlier research relating to the integration of human intervention in fire detection systems, sensor technologies, the effectiveness of automated alerts, and the role of community engagement in fire safety.

3.1 Sensor Technologies in Fire Detection

Recent studies demonstrated the possibility of becoming an efficient source of fire detection at early stages. For instance, in their study, Xie et al. (2021) focused on multi-sensor systems for residential areas and established that the combination of flame, gas, and heat sensors increases the chances of fire detection. Their results also indicate that these sensors greatly contribute to the lowering of false alarms, one of the major challenges in conventional installation systems.

3.2 Automated Alerts vs. Human Intervention

The disadvantages of fully automated fire-detection systems are quite well known. Nascimento et al. conclude in their review of the subject that "most current automated systems operate based on predefined thresholds," and it takes some time before an alert is generated when moments are critical. Human intervention, that may detect a situation more immediately, and verify whether it should be called a fire condition, may be responsible for stopping the escalation of emergencies. Their study essentially concludes that the involvement of human oversight over the processes of fire detection brings about swifter responses and better results in terms of safety in general.

3.3 Community Engagement in Fire Safety

Most studies have shown that community engagement is an important aspect of fire detection and prevention. Since residents become more vigilant as they monitor their surroundings, the chances of timely reportage are higher. Their study further illustrates an effective fire response strategy that can be formed with the integration of advanced sensor technology and community-based alert systems. This finding fits well into the general focus of our study on the need for human intervention and makes a clear case for the importance of local knowledge in discovering hazards.

3.4 Comparative Effectiveness of Detection Systems

A comparative analysis of Chen and Liu (2020) considers the detection system for fires and their different types relative to performance in varying settings. Their work shows that systems involving human judgment have better performance relative to absolutely automated ones, especially in urban settings due to higher risk of false alarms. This research supports the argument that the resultant fire detection framework would be much stronger if technological advancements and human intervention are blended together.

3.5 The Role of Mobile Applications in Fire Alerts

Recent technological advances in mobile technology have made it possible for apps that facilitate fire detection and response. More importantly, Lee et al. (2023) state that mobile apps that interact with a fire detection system are most likely to significantly improve the effectiveness of reporting and response regarding a fire incident. As simple as this is, the potential of alert verification through a mobile device shows how technological advancement can empower an individual to respond during a crisis.

4. CONCLUSIONS

In this study, we proved whether humans are relevant in a fire detection system or not, more so compared to full automated solutions. From the findings of this research paper, the conclusion drawn seems to be that technology has reached far beyond what can be conceived in terms of limits about the capabilities of fire detection systems that can be equipped with advanced sensors; yet, the human factor is still relevant for trigger-ing responses within fire emergencies. The basic perspective of human intervention circumvents the limitation of automation systems towards thresholds meant for delay alerting central systems. Community awareness and action need to be included in fire safety policies if higher overall effectiveness is to be achieved.

It gives an overview of how, when using automatic systems, it would delay detection and action on fires. Automated sensors are usually working based on set thresholds that may inhibit immediate alerts until fire conditions are marginal. For example, our proposed method - integrating human verification - will make sure even the slightest hints of fire are detected and acted on immediately. Such an approach makes fire detection not only more reliable but also lets the individual participating elements share his involvement in security. This method of triangulation in approximating the fire location was improved by the use of Haversine formula, which further reiterated the effectiveness of the former in distance determination with regard to geographical coordinates. As did Andersson et al. (2017) and Morrison and Farooq (2019), in general, the whole agreement was set upon the establishment that precise location estimation is critical in emergency response situations.

In addition, the human-in-the-loop model is a strong sense of responsibility and awareness in the community. When people are engaged to monitor their surroundings, they are likely to be more vigilant to any risk and report such risks. This is a process that contributes to a safety culture, which is important in minimizing fire hazards. Giving the firebreak/ village residents some intervention powers to verify sensor data creates a more responsive and effective fire detection framework that adapts to the nuances of real-world conditions.

On the other hand, this study supports the idea that technology must complement and supplement human judgment in emergency conditions. The integration of mobile applications with fire detection systems is a good example of how technology can be an aid to communication and situation awareness enhancement. Alerts, through the devices given to the residents, bridge the gap between automated detection and human response, thus optimizing the entire fire safety system.

In a nutshell, this technology, with regard to human engagement with fire detection, shows much promise in the advancement of community safety. Sighting the fact that humans are in fact in engagement with such technologies is one very pressing issue considering the fact that technology has so much to say in the progression of society. The frameworks of fire detection should continue being developed with this aspect of human involvement at the core, so that detection is not relied upon by mere automated means. And through this, we can provide safer environments where communities can take decisive actions on fire hazards.

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REFERENCES

Zhou, T., Zhang, L., Liu, Y., & Wang, S. (2020). Fuzzy logic systems for interpreting sensor data in fire risk assessments. *Fire Technology*, 56(3), 927-945. doi:10.1007/s10694-020-00967-5

Yoon, J., Lee, D., & Kim, H. (2018). Human-in-the-loop frameworks for fire detection: Implications for smart building systems. *Fire Safety Journal*, 99, 75-84. doi:10.1016/j.firesaf.2018.09.001

Xu, Y., & Zhao, Y. (2019). Integration of IoT with human interventions for improved fire safety. *Journal of Hazardous Materials*, 368, 177-184. doi:10.1016/j.jhazmat.2019.02.022

Kothari, S., & Kumar, R. (2021). Enhancing fire detection systems with human involvement: A review. *Safety Science*, 137, 105139. doi:10.1016/j.ssci.2021.105139

Faria, P., & Rodrigues, P. (2016). Human factors in fire safety: Exploring the interplay between technology and people. *Fire Technology*, 52(3), 695-712. doi:10.1007/s10694-015-0521-8

International Association of Fire Fighters. (2019). The role of human factors in fire safety and prevention. Retrieved from IAFF

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